Liquid helium for transferring cooling power from the cryogenic plant to the magnets and SRF cavities had been widely applied on the advanced large superconducting particle accelerators. For requirements of high stable and reliable operation, many efforts have been put into the improvement and modification of the cryogenic system.

One cryogen distribution system has been installed and commissioned to transfer liquid nitrogen and LHe from storage dewars to superconducting radio-frequency (SRF) cavities at TPS. The cryogenic system has maximum cooling capacity 890 W with associated compressors, an oil-removal system, four helium buffer tanks, one 7000-l. Dewar, gaseous helium piping at room temperature, transfer lines to distribute helium, and a transfer system for liquid nitrogen. Currently, there are two SRF cavities are located one upstream and one downstream of the distribution valve box.

Personnel safety is another critical issue of the cryogenic system. Once large liquid helium (LHe) was released on the atmospheric tunnel, the volume of helium will expand several hundred times in short time due to sudden change of its density. Therefore, cold helium discharge test in the LHC tunnel at CERN have been experimentally conducted. Numerical simulation of cold helium safety discharges had also been performed at European Spallation Source (ESS).

**NUMERICAL SIMULATION**

Detailed 3D numerical simulation was performed using a commercial general purpose CFD code ANASYS Fluent. We apply the k-ε turbulence model and SIMPLEC to solve the velocity and pressure problem.

**Governing equations**

- **Mass conservation equation**
  \[
  \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0
  \]
  where \( \rho \) is density of fluid, \( t \) is time and \( \mathbf{u} \) refers to fluid velocity vector.

- **Momentum conservation equation**
  \[
  \frac{\partial \rho \mathbf{u}}{\partial t} + \nabla \cdot (\rho \mathbf{u} \mathbf{u}) = -\nabla p + \nabla \cdot \left[ \mu \left( \nabla \mathbf{u} + \nabla \mathbf{u}^T \right) \right] - \mathbf{f}
  \]
  where \( p \) is pressure, \( \mu \) is dynamic viscosity of fluid.

- **Energy conservation equation**
  \[
  \frac{\partial \rho E}{\partial t} + \nabla \cdot (\rho \mathbf{u} E) = -\nabla \cdot (p \mathbf{u}) + \nabla \cdot (\mu \nabla \mathbf{T}) - \rho \mathbf{u} \cdot \mathbf{f}
  \]
  where \( E \) is specific internal energy, \( T \) is fluid temperature, \( k \) is heat conductivity, \( h \) is the specific internal energy of fluid.

**Boundary conditions**

- The flowrate of helium discharge was given the worst case of 4.2 kg/s by our SRF people. Time of helium discharge is 10 s. There are two simulation cases A and B in this study. Case A: Discharge helium flows vertically upward. Case B: Discharge helium flowing toward the exhaust blower on inner wall. Other initial and boundary conditions are listed as follows:
  1. Air temperature in the tunnel is 25 °C at \( t = 0s \).
  2. Discharged helium temperature is 4 K.
  3. Wall and floor are adiabatic.
  4. Both sides are opened to atmosphere (1atm).
  5. Supplied air flow velocity is 2 m/s from air exits.
  6. Back pressure of the air exhaust is 1000pa.

**EXPERIMENTAL VALIDATION**

A cubical space of 2.4 m in length, 1.2 m in width and 0.8 m in height with nitrogen discharge inside. The cubical cover was made of transparent acrylic. Another small cubic box of 1.2 m in length, 0.2 m in width and 0.4 m in height was installed inside. The nitrogen discharge exit is located on the top of the small cubic box. An air exhaust hole was located on the upper area of the wall, as shown in Fig. 5, the geometry of the experiment.

Two oxygen sensors were put on the small cubic box. The range and resolution of the sensor are 0-300% and 0.1%, respectively. Three T-type thermocouples are installed at the nitrogen inlet, air exhaust and on the box. A flowrate multi-meter is installed at the nitrogen inlet. Fig. 6 shows the experiment with nitrogen discharge in the cubic space. We also set up a 3D numerical model to simulate the experiment case. The total number of the grid elements was about 180,000. Fig. 7 shows the simulation results of O2 mass fraction. Low O2 mass fraction is shown near the nitrogen exit. The profile of low O2 mass fraction is similar to that of experimental result shown in Fig. 6. Fig. 8 shows experimental and simulation results of oxygen concentration. Although the experimental data is lower than the simulated ones, slopes of curves are close.